

CLAIMS

1. A piezoelectric/electrostrictive film type actuator which comprises: a ceramic substrate; and a piezoelectric/electrostrictive device disposed on the ceramic substrate and including a piezoelectric/electrostrictive film and electrode film and which is driven by displacement of the piezoelectric/electrostrictive device,

characterized in that the piezoelectric/electrostrictive device wherein the piezoelectric/electrostrictive film and electrode film are alternately laminated to form the electrode film from an uppermost layer and a lowermost layer possesses a plurality of layers of piezoelectric/electrostrictive films.

2. The piezoelectric/electrostrictive film type actuator according to claim 1, wherein the piezoelectric/electrostrictive device possesses two to four layers of piezoelectric/electrostrictive films.

3. The piezoelectric/electrostrictive film type actuator according to claim 1 or 2, wherein a thickness t_n of an n-th piezoelectric/electrostrictive film from bottom in the piezoelectric/electrostrictive device satisfies the following equation:

$$t_n \leq t_{n-1} \times 0.95.$$

4. The piezoelectric/electrostrictive film type actuator according to any one of claims 1 to 3, wherein a thickness per layer of the piezoelectric/electrostrictive

film is 30 μm or less.

5 5. The piezoelectric/electrostrictive film type actuator according to any one of claims 1 to 4, wherein at least one layer of the piezoelectric/electrostrictive films is formed by an electrophoresis deposition method.

6. The piezoelectric/electrostrictive film type actuator according to any one of claims 1 to 5, wherein two or more piezoelectric/electrostrictive devices are arranged on the same ceramic substrate.

10 7. The piezoelectric/electrostrictive film type actuator according to any one of claims 1 to 6 in which a cavity is formed in an internal portion of the ceramic substrate, and is pressurized by deforming a part of a wall thereof with the piezoelectric/electrostrictive device,
15 wherein the substrate is constituted of a plurality of laminated layers of thin plates.

8. The piezoelectric/electrostrictive film type actuator according to claim 7, wherein the ceramic substrate is constituted of two or three laminated layers of thin
20 plates.

9. The piezoelectric/electrostrictive film type actuator according to claim 7 or 8, wherein a thickness of a thinner portion of the ceramic substrate is 50 μm or less.

25 10. The piezoelectric/electrostrictive film type actuator according to any one of claims 1 to 9, wherein the ceramic substrate is formed of a material containing any of zirconium oxide, aluminum oxide, magnesium oxide, aluminum

nitride, and silicon nitride as a major component.

11. The piezoelectric/electrostrictive film type actuator according to any one of claims 1 to 9, wherein the ceramic substrate is formed of a material containing either
5 stabilized zirconium oxide or completely stabilized zirconium oxide which is a major component.

12. The piezoelectric/electrostrictive film type actuator according to any one of claims 1 to 11, which is used as an ink pump of a printer head disposed in an ink jet
10 printer.

13. A piezoelectric/electrostrictive film type actuator which comprises a ceramic substrate and a piezoelectric/electrostrictive device disposed on the ceramic substrate and including a piezoelectric/electrostrictive film
15 and electrode film, and said substrate being provided with a cavity being formed in an internal portion thereof and said cavity being pressurized by deforming a part of a wall of the cavity with the piezoelectric/electrostrictive device,

characterized in that the piezoelectric/
20 electrostrictive film type actuator is prepared by a method of: preparing a green sheet laminate including at least one green sheet which is a substrate and one or a plurality of green sheets in which at least one hole portion is formed and sintering the green sheet laminate to obtain a ceramic
25 laminate;

forming an electrode film (A) in the outer surface of the obtained ceramic laminate by a film forming method;

thereafter forming a piezoelectric/electrostrictive film (A) on the electrode film (A) by a film forming method, further forming an electrode film (B) on the piezoelectric/electrostrictive film (A) by the film forming
 5 method, and repeating the forming of the piezoelectric/electrostrictive film (A) and electrode film (B) once or a plurality of times;

thereafter forming a piezoelectric/electrostrictive film (B) on the electrode film (B) by the film forming method,
 10 and further forming an electrode film (C) on the piezoelectric/electrostrictive film (B) by the film forming method; and

sintering the piezoelectric/electrostrictive film and/or the electrode film predetermined times at an arbitrary
 15 timing during a period after the electrode film (A) is formed until the electrode film (C) is formed.

14. The piezoelectric/electrostrictive film type actuator according to claim 13, wherein a thickness t_n of the piezoelectric/electrostrictive film formed n-th time
 20 satisfies the following equation:

$$t_n \leq t_{n-1} \times 0.95.$$

15. The piezoelectric/electrostrictive film type actuator according to claim 13 or 14, wherein in the steps of forming and sintering the electrode film (B) at a sintering
 25 temperature $Tm1$ ($^{\circ}C$) and forming and sintering the piezoelectric/electrostrictive film (B) at a sintering temperature $Tm2$ ($^{\circ}C$), the following equation is satisfied:

$$0 \leq T_{m2} - T_{m1} \leq 300.$$

16. The piezoelectric/electrostrictive film type actuator according to any one of claims 13 to 15, wherein the piezoelectric/electrostrictive film and electrode film are
5 subjected to a plurality of film forming methods per layer and formed.

17. The piezoelectric/electrostrictive film type actuator according to any one of claims 13 to 16, wherein as the film forming method, at least one thick film forming
10 method selected from a group consisting of a screen printing method, dipping method, coating method, and electrophoresis deposition method is used.

18. The piezoelectric/electrostrictive film type actuator according to any one of claims 13 to 16, wherein as
15 the film forming method of the piezoelectric/electrostrictive film, the screen printing method is used first time, and the electrophoresis deposition method is used second and subsequent times.

19. The piezoelectric/electrostrictive film type
20 actuator according to claim 13, wherein two or three green sheets in each of which at least one hole portion is formed are laminated.

20. The piezoelectric/electrostrictive film type actuator according to any one of claims 13 to 19, which is
25 used as an ink pump of a printer head disposed in an ink jet printer.

21. A manufacturing method of a piezoelectric/

electrostrictive film type actuator which comprises a ceramic substrate and a piezoelectric/electrostrictive device disposed on the ceramic substrate and including a piezoelectric/electrostrictive film and electrode film, and
5 said substrate being provided with a cavity being formed in an internal portion thereof and said cavity being pressurized by deforming a part of a wall of the cavity with the piezoelectric/electrostrictive device,

characterized in that the method comprises:

10 a step A of preparing a green sheet laminate including at least one green sheet which is a substrate and at least one green sheet in which at least one hole portion is formed and sintering the green sheet laminate to obtain a ceramic laminate;

15 a step B of forming an electrode film (A) in the outer surface of the obtained ceramic laminate by a film forming method;

a step C of forming a piezoelectric/electrostrictive film (A) on the electrode film (A) by the film forming
20 method; and a step D of further forming an electrode film (B) on the piezoelectric/electrostrictive film (A) by the film forming method to repeat the steps C and D once or a plurality of times; and

a step E of thereafter forming a piezoelectric/
25 electrostrictive film (B) on the electrode film (B) by the film forming method; and further a step F of forming an electrode film (C) on the piezoelectric/electrostrictive film

(B) by the film forming method,

wherein sintering of the piezoelectric/
electrostrictive film and/or the electrode film is performed
predetermined times at an arbitrary timing during a period
5 after the electrode film (A) is formed until the electrode
film (C) is formed.

22. The manufacturing method of the piezoelectric/
electrostrictive film type actuator according to claim 21,
wherein a thickness t_n of the piezoelectric/electrostrictive
10 film formed n-th time satisfies the following equation:

$$t_n \leq t_{n-1} \times 0.95.$$

23. The manufacturing method of the piezoelectric/
electrostrictive film type actuator according to claim 21 or
22, wherein in the steps of forming and sintering the
15 electrode film (B) at a sintering temperature $Tm1$ ($^{\circ}C$) and
forming and sintering the piezoelectric/ electrostrictive
film (B) at a sintering temperature $Tm2$ ($^{\circ}C$), the following
equation is satisfied:

$$0 \leq Tm2 - Tm1 \leq 300.$$

20 24. The manufacturing method of the piezoelectric/
electrostrictive film type actuator according to any one of
claims 21 to 23, further comprising the steps of: subjecting
the piezoelectric/electrostrictive film and electrode film to
a plurality of film forming methods per layer to form the
25 films.

25. The manufacturing method of the piezoelectric/
electrostrictive film type actuator according to any one of

claims 21 to 24, wherein at least one thick film forming method selected from a group consisting of a screen printing method, dipping method, coating method, and electrophoresis deposition method is used as the film forming method.

5 26. The manufacturing method of the piezoelectric/
electrostrictive film type actuator according to any one of
claims 21 to 24, wherein as the film forming method of the
piezoelectric/electrostrictive film, the screen printing
method is used first time and the electrophoresis deposition
10 method is used second and subsequent times.

 27. The manufacturing method of the piezoelectric/
electrostrictive film type actuator according to claim 21,
wherein the step A includes a step of preparing one or a
plurality of laminated green sheets which form the substrate
15 and in each of which at least one hole portion is formed.

 28. The manufacturing method of the piezoelectric/
electrostrictive film type actuator according to claim 27,
further comprising the steps of: laminating two or three
green sheets in each of which at least one hole portion is
20 formed.

 29. The manufacturing method of the piezoelectric/
electrostrictive film type actuator according to any one of
claims 21 to 28, wherein the actuator is used as an ink pump
of a printer head disposed in an ink jet printer.